REMARKS

In response to the Final Office Action, Claim 1 is amended and Claim 15 is cancelled. Claims 1-14 remain in the Application. Reconsideration of the pending claims is respectfully requested in view of the above amendments and the following remarks.

I. Examiner Interview Summary

Applicants conducted an interview with Examiner Van Roy on May 15, 2007 to discuss amendments to Claim 1. The Examiner agreed that the prior art rejection can be overcome if Applicants can show that the term "self-mode locking" is understood in the art to be distinct from the TM and TE mode switching disclosed in the cited references.

II. Claims Rejected Under 35 U.S.C. § 103(a)

A. Claims 1-6 and 11-12 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent No. 5,841,799 issued to Hiroki ("Hiroki") in view of U.S. Patent No. 6,018,541 issued to Huang ("Huang"). Applicants respectfully traverse the rejection.

To establish a *prima facie* case of obviousness, the relied upon references must teach or suggest every limitation of the claim such that the invention as a whole would have been obvious at the time the invention was made to one skilled in the art.

Among other elements, Amended Claim 1 recites:

> "A self-mode locked multi-section semiconductor laser diode, for generating high-frequency optical pulsation and controlling the pulsation frequency.... wherein the multi-section semiconductor laser diode outputs high-frequency optical pulsation according to self mode-locking of compound cavity modes, and the phase and strength of the feedback laser light can be adjusted to vary the pulsation frequency in a wide range."

Applicants submit that Hiroki in view of Huang does not teach or suggest at least these elements of Claim 1.

In the Response to Argument, the Examiner indicates that Claim 1 does not clearly state that the pulsation is generated by the laser alone. Applicants amend Claim 1 to more clearly

recite that "the multi-section semiconductor laser diode outputs high-frequency optical pulsation." Thus, amended Claim 1 clearly recites that the pulsation is generated by the multi-section semiconductor laser diode.

Further, Applicants amend Claim 1 to recite that "the multi-section semiconductor laser diode outputs high-frequency optical pulsation according to self mode-locking of compound cavity modes" (emphasis added). The cited references do not teach or suggest that the pulsation is generated according to self-mode locking of compound cavity modes. Hiroki does not disclose a multi-section semiconductor laser diode that generates high-frequency optical pulsation according to self-mode locking of compound cavity modes. Rather, Hiroki discloses a laser that outputs TM mode and TE mode light and an external polarize that blocks either the TM or TE mode light. A laser that switches its output between the TM and TE modes is not a self-mode locking laser and, therefore, does not generate pulsation according to self mode-locking principles.

A self-mode locking laser is also known as a passive mode-locking laser (see, e.g., U.S. Patent No. 6,563,852 issued to Baillargeon, et al., col. 1, lines 55-56). A passive mode-locking laser typically includes a component that attenuates low-intensity light and causes the amplification of high-intensity light (see, e.g., http://en.wikipedia.org/wiki/Modelocking, section "Passive Modelocking"). An article that reports the original concept and experiment of self mode-locking laser can be found in: A. J. DeMaria, D. A. Stetser, and H. Heynau, "Self mode-locking of lasers with saturable absorbers", Appl. Phys. Lett. 8, 174 (1966), which is attached to this Response as Appendix A. These articles disclose that the self mode-locking involves selective transmission of the light based on light intensity, and does not involve the manipulation of TM and TE modes. Thus, the self mode-locking as recited in Claim 1 involves no TM and TE mode switching. Thus, Hiroki does not teach or suggest each element of amended Claim 1.

Huang does not cure the defects of Hiroki. Huang is relied on for disclosing a complex-coupled DFB laser section. However, Huang does not teach or suggest the claimed multi-section semiconductor laser diode that generates high-frequency optical pulsation according to self mode-locking of compound cavity modes.

In the rejection of Claim 15, which is now cancelled, the Examiner relies on U.S. Patent No. 5,220,573 issued to Sakata et al ("Sakata") for disclosing the multi-section laser diode to output optical pulses. Sakata discloses an integrated polarizer which allows transmission of forward TE light but blocks the backward-propagating TM light. For similar reasons mentioned above, Sakata also does not teach or suggest the claimed multi-section semiconductor laser diode that generates high-frequency optical pulsation according to self mode-locking of compound cavity modes.

Thus, the cited references do not teach or suggest each of the elements of amended Claim 1. Claims 2-6 and 11-12 depend from Claim 1 and incorporate the limitations thereof. Thus, for at least the reasons mentioned above in regard to Claim 1, these claims are non-obvious over Hiroki in view of Huang. Accordingly, reconsideration and withdrawal of the § 103 rejection of Claims 1-6 and 11-12 are requested.

B. Claim 9 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Hiroki and Huang in view of U.S. Patent No. 5,177,758 issued to Oka et al ("Oka").

Claim 9 depends from Claim 1 and incorporates the limitations thereof. Thus, for at least the reasons mentioned above in regard to Claim 1, Hiroki and Huang do not teach or suggest each of the elements of Claim 9.

Oka is relied on for disclosing a central axis of a phase control section that aligns with the active sections. However, Oka does not teach or suggest does not teach or suggest the claimed multi-section semiconductor laser diode that generates high-frequency optical pulsation according to self mode-locking of compound cavity modes. Thus, Hiroki and Huang in view of Oka do not teach or suggest each of the elements of amended Claim 1 and its dependent claim, namely, Claim 9. Accordingly, reconsideration and withdrawal of the § 103 rejection of Claim 9 is requested.

C. Claim 13 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Hiroki and Huang in view of U.S. Patent No. 4,995,048 issued to Kuindersma et al ("Kuindersma").

Claim 13 depends from Claim 1 and incorporates the limitations thereof. Thus, for at least the reasons mentioned above in regard to Claim 1, Hiroki and Huang do not teach or suggest each of the elements of Claim 13.

Kuindersma is relied on for disclosing an amplifier section located between a DFB and the phase control sections. However, Kuindersma does not teach or suggest the claimed multi-section semiconductor laser diode that generates high-frequency optical pulsation according to self mode-locking of compound cavity modes. Thus, Hiroki and Huang in view of Kuindersma do not teach or suggest each of the elements of amended Claim 1 and its dependent claim, namely, Claim 13. Accordingly, reconsideration and withdrawal of the § 103 rejection of Claim 13 is requested.

D. Claim 14 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Hiroki and Huang in view of U.S. Patent No. 6,031,860 issued to Nitta et al ("Nitta").

Claim 14 depends from Claim 1 and incorporates the limitations thereof. Thus, for at least the reasons mentioned above in regard to Claim 1, Hiroki and Huang do not teach or suggest each of the elements of Claim 14.

Nitta is relied on for disclosing the use of an HR coating. However, Nitta does not teach or suggest the claimed multi-section semiconductor laser diode that generates high-frequency optical pulsation according to self mode-locking of compound cavity modes. Thus, Hiroki and Huang in view of Nitta do not teach or suggest each of the elements of amended Claim 1 and its dependent claim, namely, Claim 14. Accordingly, reconsideration and withdrawal of the § 103 rejection of Claim 14 is requested.

E. Claim 15 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Hiroki and Huang in view of U.S. Patent No. 5,220,573 issued to Sakata et al ("Sakata").

Claim 15 is cancelled.

III. Allowable Subject Matter

Applicants note with appreciation the Examiner's indication that Claims 7, 8, and 10 would be allowable if rewritten in independent form. Applicants submit that the amendments to Claim 1 have placed these dependent claims in condition for allowance. Accordingly, reconsideration and withdrawal of the objection of Claims 7, 8, and 10 are requested.

CONCLUSION

In view of the foregoing, it is believed that all claims are now in condition for allowance and such action is earnestly solicited at the earliest possible date. If there are any additional fees due in connection with the filing of this response, please charge those fees to our Deposit Account No. 02-2666.

Respectfully submitted,

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Dated: June 1, 2007

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Marilyn Bass June 01, 2007

Attachment: Appendix A

on the diode evaluations result from uncertainties in the nonlinear dielectric behavior[4] and nonuniformities in donor concentration on a given slice.

It would seem from the above evidence that the measured carrier concentration most likely results from calcium replacing potassium substitutionally. This evidence, however, does not rule out possibilities involving compensation by nonstoichiometric electrically active imperfections, (e.g. oxygen vacancies) and/or metallic impurities other than calcium (e.g. Sn^{4+}, Fe^{3+}, etc.).[3] The consideration of the stoichiometry of the crystal involves a complex analysis and is assumed unimportant in the substitutional model proposed. It is worthwhile to note that x-ray fluorescence and net ionized donor concentration measurements were also made on samples grown[5] in two other furnaces without the intentional addition of calcium to the flux. The results of these measurements are consistent with calcium replacing potassium in the crystal. All the crystals have concentrations of calcium larger than that initially present in the flux, indicating that calcium is rapidly depleted from the flux. The principal result of this Letter, however, is that the calcium concentration approximates the net ionized donor concentration in conducting $KTaO_3$ pulled from the melt.

The authors acknowledge the discussions with D. Kahng, S. H. Wemple, G. E. Smith, and W. A. Bonner. They also thank V. J. DeLucca and E. W. Chase for building the furnace and designing the control apparatus, and give a special note of gratitude to F. V. DiMarcello who supplied a top plug coated with calcium aluminate, which initially made our crystals go from insulating to conducting.

[1]S. H. Wemple, Thesis, MIT, 1963 (unpublished).
[2]W. A. Bonner, private communication.
[3]S. H. Wemple, "Some Transport Properties of Oxygen-Deficient Single-Crystal Potassium Tantalate ($KTaO_3$)," *Phys. Rev.* **137**, A1575 (1965).
[4]D. Kahng and S. H. Wemple, "Measurement of Nonlinear Polarization of $KTaO_3$ Using Schottky Diodes," *J. Appl. Phys.* **36**, 2925 (1965).
[5]The samples were obtained from S. H. Wemple and W. A. Bonner.

SELF MODE-LOCKING OF LASERS WITH SATURABLE ABSORBERS

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(regenerative pulse oscillator; bleachable dyes; E)

(Received 25 January 1966)

Cutler[1] described the operation of a microwave regenerative pulse generator which consisted of a feedback loop encompassing an amplifier, a filter, a delay line, and a circuit called the expandor. (See Fig. 1*a*.) The function of these elements are all familiar with the possible exception of the expandor, whose function was to provide less attenuation for a high level signal than for a low level signal. The expandor prevented the degradation (by noise and distortion) of a pulse recirculating indefinitely around the feedback loop by providing the following desirable effects: 1) emphasizing the highest amplitude of the recirculating pulse, 2) reducing the lower amplitudes, 3) discriminating against noise and reflections, and 4) acting to shorten the pulse until the pulse width is limited by the frequency response of the circuit. The output of the regenerative pulse oscillator had a pulse rate equal to the reciprocal of the loop delay, pulse widths inversely equal to the overall system bandwidth, and a center frequency determined by the median filter frequency.

A laser possesses all the basic elements of Cutler's regenerative pulse generator with the possible exception of the expandor element. (See Fig. 1*b*.)

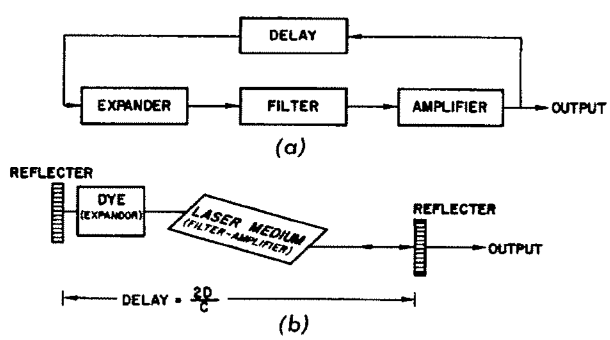

Fig. 1. Equivalence of (*a*) Cutler's regenerative pulse generator and (*b*) a laser with a saturable absorber inserted within its feedback interferometer.

APPENDIX A

The laser medium serves as the amplifier, the combination of the Fabry-Perot resonances and the line width of the laser transition serve as the filter, and the time required for an optical pulse to traverse twice the distance between the reflectors serves as the loop time-delay. In the past, lasers were operated as pulse-regenerative oscillators by coupling the optical modes with a time-varying loss (having a frequency commensurate with the axial mode spacing frequency) inserted into the feedback interferometer.[2–4] It has also been reported that the nonlinear gain characteristics of the inverted population of a laser medium can also serve as an expandor element if the Q of the laser cavity and the position of the active medium are judiciously adjusted.[3,5]

The purpose of this Letter is to report that saturable absorbers, such as reversible bleachable dye solutions commonly used as laser Q-switches, are well suited for use as expandor elements in the optical region if the dye's recovery time is shorter than the loop time-delay of the laser.[6] The advantages of a bleachable dye expandor element arise from its ability to automatically obtain mode-locking without having to critically adjust mirror spacing, modulating frequency, Q of the cavity, laser position, or compensate for any optical length perturbations of the feedback interferometer. The latter is of particular importance in the mode-locking of large solid-state lasers as a consequence of the optical length variation of the rods during the optical pumping flash.

Simultaneous Q-switching and mode-locking experiments with saturable dyes were performed with 12.2-cm-long by 0.95-cm-diam and 76-cm-long by 1.9-cm-diam Nd^{3+}-doped glass rods. The ends of the rods were polished at Brewster's angle. Two external dielectric reflectors having reflectivities of 99% and 70% (for the smaller rod) and 99.9% and 5% (for the larger rod) were utilized for the laser's feedback interferometer. The reflectivities of the feedback interferometer were not found to be critical for obtaining mode-locking. The rods were optically pumped with linear flash lamps which were optically coupled to the rods with closely wrapped silver foil. The smaller rod was air-cooled while the larger rod was submerged in water. The response time of the overall detection system [a ITT model F4018 (S-1) biplanar photodiode and a traveling wave oscilloscope] was just under 0.5×10^{-9} sec. Eastman-9740 reversible dye solution was used as the saturable absorber. The optical cell containing the dye was placed within the feedback

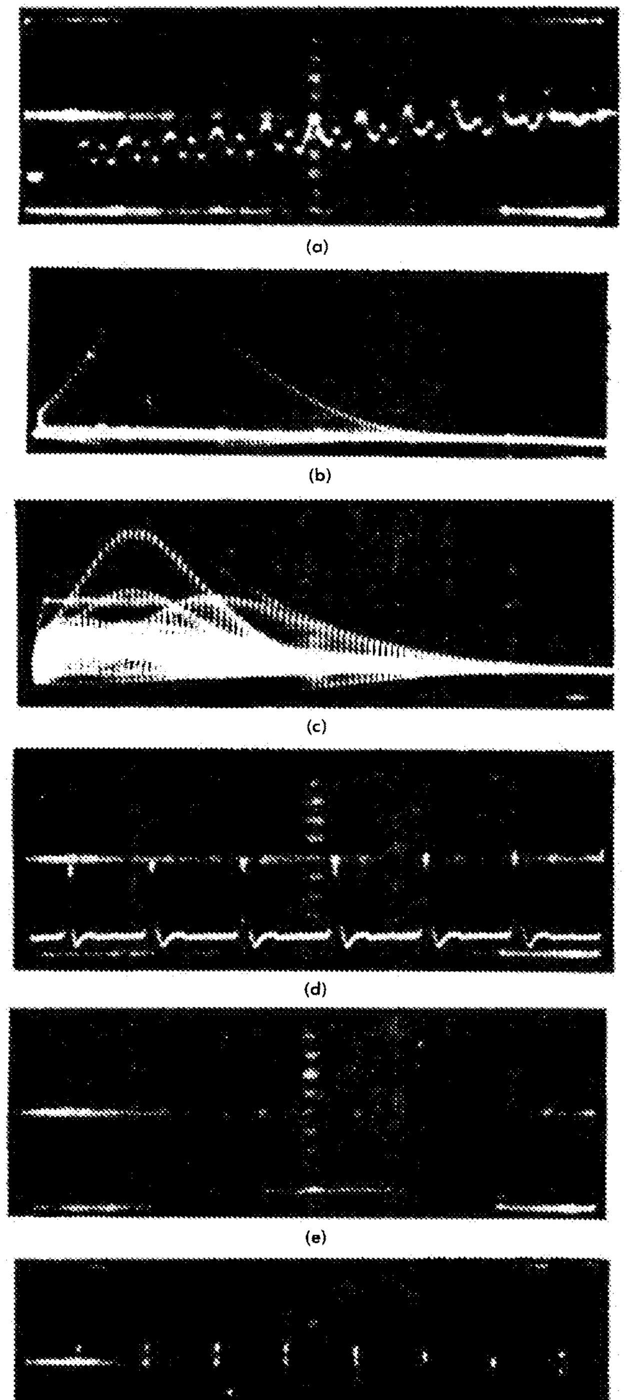

Fig. 2. Oscillograms of the output of simultaneous Q-switched and mode-locked Nd^{3+}-doped glass lasers. Sweep speeds: (*a*) 5 nsec/div; (*b*) 200 nsec/div; (*c*) 50 nsec/div; (*d*) 10 nsec/div; (*e*) 2 nsec/div; (*f*) 20 nsec/div. Figures 2*a–f* were taken with a 12.2-cm-long by 0.95-cm-diam rod and Fig. 2*g* was taken with a 76-cm-long by 1.9-cm-diam rod.

interferometer near either of the two reflectors. The position of the rods as a function of distance from either reflector was not found to be critical.

By judiciously adjusting the absorption coefficient of the dye solution and the flash lamp's capacitor bank voltage, the tendency of the saturable dye to emphasize the highest amplitude fluctuation occurring at the initiation of laser oscillation and to shorten this fluctuation's pulse width as it successively porpoagates through the saturable absorption cell was recorded as illustrated by Fig. 2*a*. Figure 2*a* illustrates an oscillogram of the smaller rod's output for 3×10^{-8} sec (5×10^{-9} sec/div sweep speed) of the early portions of a slow built-up, Q-switched pulse. At the end of 3×10^{-8} sec, the smaller pulse is practically completely eliminated, the pulse halfwidth is reduced to 0.5×10^{-9} sec and the pulse repetition period ($\tau = 2.5 \times 10^{-9}$ sec) is equal to $(2D)/c$, where D is the optical path length (37.5 cm in this case) between the reflectors. An oscillogram of an entire simultaneous mode-locked and Q-switched pulse is illustrated by Fig. 2*b* at a sweep speed of 2×10^{-7} sec/div. As the pumping intensity was increased, multiple Q-switched pulses occurred. Figure 2*c* illustrates the mode-locking of the multiple Q-switched laser's output as recorded with the oscilloscope operated in a multiple trace mode at a sweep speed of 5×10^{-8} sec/div. Figure 2*d* depicts the mode-locked output of the smaller rod at a sweep speed of 10×10^{-9} sec/div. The recorded pulse halfwidths are approximately 5×10^{-10} sec and the repetition period is 9.2×10^{-9} sec for an optical round-trip path length of 276 cm between the reflectors. Mode-locking was obtained with reflector separations from 30 cm to 220 cm. An oscillogram of a single mode-locked pulse at a sweep speed of 2×10^{-9} sec/div is illustrated by Fig. 2*e*. Notice that the rise time of the pulse equals the overall rise time of the system. If the absorbing cell was placed within the interferometer at some arbitrary distance from either of the two reflectors, double pulses were frequently obtained. The spacing of these double pulses corresponded to the separations of the cell from the reflectors. Figure 2*f* illustrates the mode-locked output of the larger rod at a sweep speed of 2×10^{-8} sec. The pulse repetition period of 14.6×10^{-9} sec corresponds to the transit time required for the optical pulse to complete a round trip of 4.4 m between the reflectors. The output energy of the Q-switched pulse from the smaller rod averaged approximately 2×10^{-2} J and the energy of the largest amplitude mode-locked pulse within the Q-switched envelope averaged approximately 10^{-3} J with a peak power of 2 to 3 MW as determined from oscilloscope and calorimeter measurements. No efforts were made to maximize the output energy or peak power during this work. The harmonic content of the simultaneous Q-switched and mode-locked pulses was measured with a 3.4-m Jarrel-Ash spectrometer and was found to be approximately 100-Å wide (or $\sim 2.7 \times 10^{12}$ Hz). To a first approximation, the minimum pulse width obtainable with such a line width is $\sim 3.7 \times 10^{-13}$ sec.

The authors acknowledge the experimental assistance of H. Tourtellotte and R. Bodurtha during the course of this work. The efforts of A. W. Penney in eliminating the ringing of the detector as was evident in a previous publication by one of the authors[7] is also gratefully acknowledged. The design of the detector will be published shortly elsewhere.

[1] C. C. Cutler, *Proc. IRE* **43**, 140 (1955).

[2] L. E. Hargrove, R. L. Fork, and M. A. Pollack, *Appl. Phys. Letters* **5**, 4 (1964).

[3] M. H. Crowell, *J. Quantum Elect.* **1**, 12 (1965).

[4] M. DiDomenico, Jr., *J. Appl. Phys.* **33**, 2870 (1964); A. Yariv, *J. Appl. Phys.* **36**, 388 (1965).

[5] R. E. McClure, *Appl. Phys. Letters* **7**, 148 (1965).

[6] It was recently brought to our attention that H. W. Mocker and R. J. Collins, [*Appl. Phys. Letters* **7**, 270 (1965)], have operated a ruby laser as a pulse-regenerative oscillator by the insertion of saturable absorbers into the feedback interferometer.

[7] A. J. DeMaria, C. Ferrar, and G. E. Danielson, Jr., *Appl. Phys. Letters* **8**, 22 (1966).